MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2017/2018

ETM7136 – DIGITAL COMMUNICATION SYSTEMS AND DESIGN

(M.Eng.Tele)

26 OCTOBER 2017
8.00 p.m. – 11.00 p.m.
(3 Hours)

INSTRUCTIONS TO STUDENTS

1. This examination paper consists of **8 printed pages** (including the cover page) with **4 questions only**.

2. **Attempt ALL questions.** All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided. **Show all relevant steps** to obtain maximum marks.

Question 1

(a) Calculate the normalized energy for the following waveforms:

(i) $w(t)=\begin{cases}3.5\cos(200\pi t), & \text{for } -0.005 \le t \le 0.005\\ 0, & \text{elsewhere}\end{cases}$.

[3.5 marks]

(ii) $y(t)=\begin{cases}8e^{(-3t)}, & \text{for } t>0\\ 0, & \text{elsewhere}\end{cases}$.

[3.5 marks]

(b) Consider a signal $m(t)=A\sin\omega_0 t$. The autocorrelation function of $m(t)$ is $R_m(\tau)=\frac{A^2}{2}\cos\omega_0\tau$. Determine the power spectral density of $m(t)$.

[3 marks]

(c) You have been selected as a member of a project group to study a new communication waveform $z(t)$. The two-sided power spectral density of this waveform is given by

$$G_z(f)=\begin{cases}10^{-10}f^2, & -7.8\text{kHz} \le f \le 7.8\text{kHz}\\ 0, & \text{elsewhere}\end{cases}.$$

(i) Calculate the normalized average power in $z(t)$ over all frequency band.

[3 marks]

(ii) Compute the normalized average power in $z(t)$ contained in the frequency band between 3 kHz to 6 kHz.

[3 marks]

(iii) If the normalized average power contained between 0 to x kHz is calculated to be 5 W, what is the value of the frequency x?

[3 marks]

(d) A cordless phone operates at a signal-to-noise ratio (SNR) of 29 dB and utilizes a bandwidth of 3800 Hz. The cordless phone is to be designed to transmit and receive voice simultaneously (i.e. full duplex) over this line without errors.

(i) Can the system achieve error free transmission at a bit rate of 48 kbps? Justify your answer.

[3 marks]

(ii) Determine the minimum SNR (in decibels) required for error free transmission rate if the intended transmission rate is 35 kbps.

[3 marks]

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Question 2

(a) Figure Q2.1 shows the spectrum of an analogue signal. The analogue signal is sampled using natural sampling at a sampling rate of 10 kHz with pulse width of $\tau = 50\ \mu s$.

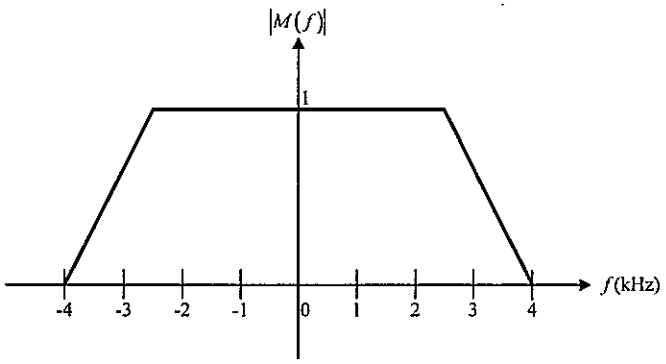

Figure Q2.1

(i) Does aliasing (spectral overlapping) occur in this natural sampling process? Justify your answer.

[2 marks]

(ii) Plot the magnitude spectrum of the naturally sampled signal.

[3 marks]

(iii) Suggest a method to recover the analogue signal from the naturally sampled signal.

[1 mark]

(b) The signal $x(t) = 5\cos(2\pi t)$ is digitized using a 4-bit pulse code modulation (PCM) system. The quantizer is of the midrise type, with a step size of 1 V as shown in Figure Q2.2. Assume that the sampling rate is 4 Hz, with samples taken at t = 1/8, 3/8, 5/8, 7/8 seconds.

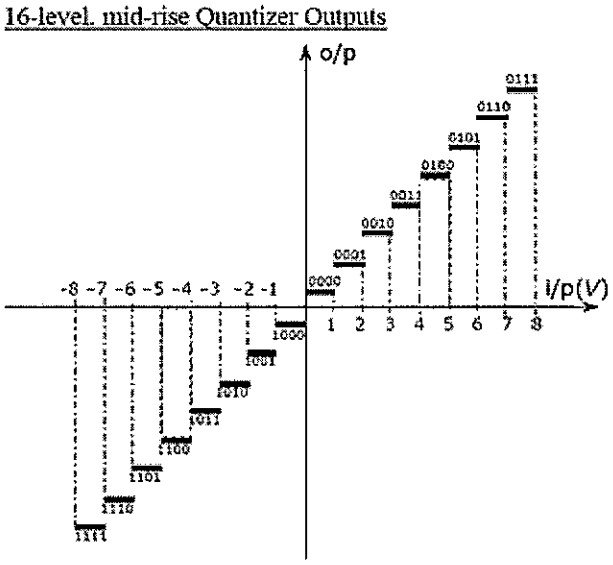

Figure Q2.2

Continued...

Question 2

(b)

(i) Sketch the resulting PCM waveform using unipolar return-to-zero (RZ) line code for one complete cycle of $x(t)$.

[6 marks]

(ii) Compute the bit rate of the PCM system.

[1 mark]

(iii) Explain the overload noise and hunting noise associated with quantizer.

[3 marks]

(c) State one advantage of differential pulse code modulation (DPCM) over PCM.

[2 marks]

(d) A 16-level pulse amplitude modulation (PAM) transmit binary data at the rate of 20Mbits/s.

(i) Determine the minimum transmission bandwidth required to avoid inter-symbol interference (ISI).

[3 marks]

(ii) Assume that the overall equivalent transfer function is of the raised cosine type with roll-off factor r and the transmission bandwidth is 3 MHz. Compute the maximum permissible value of r.

[4 marks]

Question 3

(a) A matched filter has the impulse response

$$h(t) = \begin{cases} -\frac{A}{2}, & 0 \le t \le \frac{T}{2} \\ \frac{A}{2}, & \frac{T}{2} \le t \le T \end{cases}.$$

Sketch the input signal $s(t)$, to which the filter is matched.

[2 marks]

Continued...

Question 3

(b) Consider a baseband binary communication system with equally likely signalling that transmits signals $s_i(t)$, where $i = 1, 2$. The receiver test statistic $z(T) = a_i + n_0$, where the signal component a_i is either $a_1 = +1$ or $a_2 = -1$ and the noise component n_0 has a uniform distribution. The conditional density functions $p(z \mid s_i)$ are given by

$$p(z \mid s_1) = \begin{cases} \frac{1}{2} & \text{for } -0.2 \le z \le 1.8 \\ 0 & \text{otherwise} \end{cases}$$

and

$$p(z \mid s_2) = \begin{cases} \frac{1}{2} & \text{for } -1.8 \le z \le 0.2 \\ 0 & \text{otherwise} \end{cases}.$$

Evaluate the probability of a bit error if an optimum decision threshold is used.

[4 marks]

(c) Distinguish the following:

(i) Coherent demodulation and noncoherent demodulation.

[3 marks]

(ii) Slow-frequency hopping and fast-frequency hopping.

[3 marks]

(d) Figure Q3.1 shows two quadrature phase-shift-keying (QPSK) constellations for a π/4-QPSK modulator.

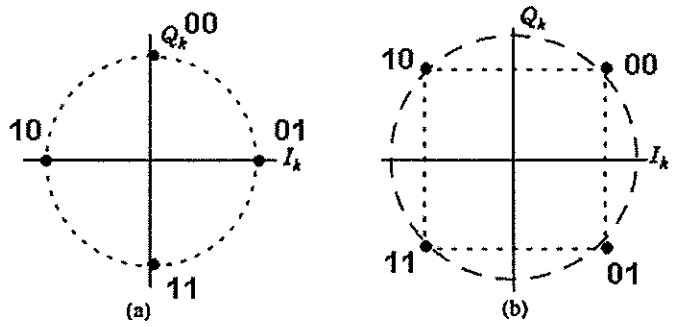

Figure Q3.1

(i) State one advantage of π/4-QPSK modulation technique over QPSK.

[1 mark]

(ii) Determine the carrier phase shifts when input data stream is 001101101110. Assume that the modulation starts from scheme (a) and the leftmost bits are first applied to the modulator.

[2 marks]

(iii) A π/4-QPSK signal is used to send data at a rate of 1.5 Mbits/s over a channel with a bandwidth of 1.3 MHz. If the signal is equalised to have an equivalent raised cosine filter characteristic, determine the maximum permissible value of rolloff factor *r*.

[4 marks]

Continued...

Question 3

(e) Error-control coding forms an integral part in the design of a transmission system. Explain the design trade-offs when employing error control coding.

[3 marks]

(f) Consider the block code shown in the Table 3.1.

Table 3.1

Information	Codeword
00	00000
01	01011
10	10101
11	11110

(i) Is this a systematic code? Justify your answer.

[1.5 marks]

(ii) Is this a linear code? Justify your answer.

[1.5 marks]

Question 4

(a) Consider a (n, k) code whose generator matrix $\boldsymbol{G}$ is

$$\boldsymbol{G} = \begin{bmatrix} 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 \end{bmatrix}$$

(i) Determine the values of n and k.

[2 marks]

(ii) List down all the valid codewords for this code.

[4 marks]

(iii) Find the minimum Hamming distance for this code.

[2 marks]

(iv) Determine the maximum error-detecting capability and the maximum error-correcting capability of this code.

[2 marks]

(b) A convolutional code is described by the following impulse responses:

$$g_1 = [1\ 0\ 1],\ g_2 = [1\ 1\ 0].$$

(i) Sketch the encoder corresponding to this code.

[2 marks]

(ii) Determine the code rate and constraint length of this code.

[3 marks]

(iii) Sketch the state-transition diagram for this code.

[3 marks]

(c) Trellis coded modulation (TCM) is a bandwidth efficient transmission scheme that can achieve high coding gain by integrating coding and modulation.

(i) Discuss three main features of TCM.

[6 marks]

(ii) Give two examples of modern communication systems that use TCM.

[1 mark]

Continued...

Appendix I: Fourier Transform Pairs

Pair Number	$x(t)$	$X(f)$
1.	$\Pi\left(\frac{t}{\tau}\right)$	$\tau \operatorname{sinc} \tau f$
2.	$2W \operatorname{sinc} 2Wt$	$\Pi\left(\frac{f}{2W}\right)$
3.	$\Lambda\left(\frac{t}{\tau}\right)$	$\tau \operatorname{sinc}^2 \tau f$
4.	$\exp(-\alpha t)u(t),\ \alpha > 0$	$\frac{1}{\alpha + j2\pi f}$
5.	$t \exp(-\alpha t)u(t),\ \alpha > 0$	$\frac{1}{(\alpha + j2\pi f)^2}$
6.	$\exp(-\alpha\|t\|),\ \alpha > 0$	$\frac{2\alpha}{\alpha^2 + (2\pi f)^2}$
7.	$e^{-\pi(t/\tau)^2}$	$\tau e^{-\pi(f\tau)^2}$
8.	$\delta(t)$	1
9.	1	$\delta(f)$
10.	$\delta(t - t_0)$	$\exp(-j2\pi f t_0)$
11.	$\exp(j2\pi f_0 t)$	$\delta(f - f_0)$
12.	$\cos 2\pi f_0 t$	$\frac{1}{2}\delta(f - f_0) + \frac{1}{2}\delta(f + f_0)$
13.	$\sin 2\pi f_0 t$	$\frac{1}{2j}\delta(f - f_0) - \frac{1}{2j}\delta(f + f_0)$
14.	$u(t)$	$(j2\pi f)^{-1} + \frac{1}{2}\delta(f)$
15.	$\operatorname{sgn} t$	$(j\pi f)^{-1}$
16.	$\frac{1}{\pi t}$	$-j \operatorname{sgn}(f)$
17.	$\hat{x}(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{x(\lambda)}{t - \lambda}\, d\lambda$	$-j \operatorname{sgn}(f) X(f)$
18.	$\sum_{m=-\infty}^{\infty} \delta(t - mT_s)$	$f_s \sum_{m=-\infty}^{\infty} \delta(f - mf_s),$ $f_s = T_s^{-1}$

Continued...

Appendix II: Fourier Transform Properties

Name of Theorem		
1. Superposition (a_1 and a_2 arbitrary constants)	$a_1x_1(t) + a_2x_2(t)$	$a_1X_1(f) + a_2X_2(f)$
2. Time delay	$x(t - t_0)$	$X(f)e^{-j2\pi ft_0}$
3a. Scale change	$x(at)$	$\lvert a\rvert^{-1}X\left(\frac{f}{a}\right)$
b. Time reversal	$x(-t)$	$X(-f) = X*(f)$
4. Duality	$X(t)$	$x(-f)$
5a. Frequency translation	$x(t)e^{jf_0t}$	$X(f - f_0)$
b. Modulation	$x(t)\cos\omega_0t$	$\frac{1}{2}X(f - f_0) + \frac{1}{2}X(f + f_0)$
6. Differentiation	$\frac{d^nx(t)}{dt^n}$	$(j2\pi f)^nX(f)$
7. Integration	$\int_{-\infty}^{t} x(t')\,dt'$	$(j2\pi f)^{-1}X(f) + \frac{1}{2}X(0)\delta(f)$
8. Convolution	$\int_{-\infty}^{\infty} x_1(t - t')x_2(t')\,dt'$	$X_1(f)X_2(f)$
	$= \int_{-\infty}^{\infty} x_1(t')x_2(t - t')\,dt'$	
9. Multiplication	$x_1(t)x_2(t)$	$\int_{-\infty}^{\infty} X_1(f - f')X_2(f')\,df'$
		$= \int_{-\infty}^{\infty} X_1(f')X_2(f - f')\,df'$

End of Paper